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Supplementary information

Effects of microplastics and nanoplastics on the kidney and cardiovascular system

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Supplementary Information

Table S1. Natural products mitigate particulate plastic-induced damages.

Natural products	Natural products' concentrations and frequency of exposure	Particulate plastics' concentrations, sizes and frequency of exposure	Protective effects
Ginkgetin (Ginkgo biloba)[1]	25 mg/kg, 30 days	PS-MPs, 0.01 mg/kg, 30 days, an albino rat model	1. Increased levels of antioxidants, anti-inflammatory effects, and anti-apoptotic properties. 2. Decreased ROS and MDA levels. 3. Lowered creatinine, urobilinogen, urea, serum NGAL and urinary KIM-1 levels. 4. Decreased histopathological damage in the rat renal tissues.
Tamarixetin (*Tamarix ramosissima, Azadirachta indica,* and *Psidium guajava*)[2]	50 mg/kg, 30 days	PS-MPs, oral gavage, 0.01 mg/kg, 30 days, an albino rat model	1. Increased levels of Nrf2 and decreased levels of Keap-1. 2. Decreased levels of hepatic function markers, oxidative stress markers and inflammatory indices. 3. Increased antioxidant activity and anti-apoptotic properties. 4. Decreased histopathological changes in rat hepatic tissues.
Astragalin (*Cuscuta chinensis*)[3]	50 mg/kg, 30 days	PS-MPs, oral gavage, 0.01 mg/kg, 30 days, an albino rat model	1. Increased levels of Nrf2 and decreased levels of Keap-1. 2. Decreased hepatic function markers, oxidative stress markers and inflammatory markers. 3. Increased antioxidant activity and anti-apoptotic properties. 4. Recovered histopathological injuries of rat liver tissues.

Rhamnetin (Clove, apple, sour cherries and vegetables)[4]	50 mg/kg, 56 days	PS-MPs, oral gavage, 0.01 mg/kg, 56 days, an albino rat model	1. Decreased oxidative stress markers and inflammatory markers. 2. Increased antioxidant activity and anti-apoptotic properties. 3. Increased sperm progressive motility. 4. Increased levels of steroidogenic enzymes. 5. The number of germ cells in rats was increased, and testicular impairments were restored.
Astilbin (*Drimys brasiliensis, Hypericum perforatum, Desmos chinensis, Vitis vinifera, Engelhardia roxburghiana*, and *genus smilax*)[5]	20 mg/kg, 56 days	100 nm PS-NPs, oral gavage, 0.01 mg/kg, 56 days, a rat model	1. Decreased oxidative stress markers and inflammatory markers. 2. Increased antioxidant activity and anti-apoptotic properties. 3. Increasing epididymal sperm number, viability and motility. 4. Increased levels of steroidogenic enzymes and hormones. 5. Protect the tissues of the testicles in rats.
Didymin (Campanula and citrus fruits include mandarin, orange, bergamot and oregano)[6]	1 mg/kg, 30 days	PS-NPs, oral gavage, 50 μg/kg 30 days, a rat model	1. Increased levels of Nrf2 and decreased levels of Keap-1. 2. Reduced hepatic function markers, oxidative stress markers and inflammatory indices. 3. Increased antioxidant activity and anti-apoptotic properties. 4. Decreased histopathological damages in rat hepatic tissues.
DHA-PS (herring (Clupea harengus) roes)[7]	50 mg/kg/day, 6 weeks	100 nm PS-NPs, intragastric administration, 25 mg/kg/day, 6 weeks, a mouse model	1. Decrease of IL-6, IL-1β, TNF-α and MDA. 2. Increase of IL-10 and activities of SOD, GSH-Px and CAT. 3. Reducing lipid disorders primarily by modifying linoleic acid metabolism, renal glycerophospholipid metabolism and the SIRT1-AMPK pathway.

Table S2. The potential risks and the measures for preventing particulate plastic contamination during kidney replacement therapy[8,9].

	Potential risks	Measures
Reverse Osmosis (RO) system integrity	- Malfunctions in the filtration system can compromise the RO membrane by introducing particulate plastics into the patient. - The use and deterioration of synthetic materials within RO membranes have become an additional source of particulate plastics.	1. Regularly maintain and monitor the RO systems to prevent fouling[10], the leading cause of membrane failure in 75% of instances. 2. Upgrade and regularly monitor the RO membranes to ensure optimal performance and longevity of the water treatment system.
Material selection and handling	- Using plastic pipes for water transport during dialysate preparation, including storage tanks and distribution systems, may release particulate plastics into dialysate water, posing exposure risks to patients undergoing dialysis therapy. - Particulate plastics may leach from the acid concentrate containers and bicarbonate bags in the post-RO process.	1. Regular inspections of acid concentrate containers and bicarbonate bags to assess the risks of particulate plastics leaching. 2. Regular softener and carbon filter system maintenance to remove disinfection by-products (DBPs) and particulate plastics from dialysate water. 3. Review and select the plastic pipes and water storage tanks with safer alternatives to minimize the potential for particulate plastic leaching.
Dialysate quality control and sterilization process	- Dialyzers, primarily composed of plastic polymer materials, could be a significant source of particulate plastics. - The sterilization processes, especially those involving irradiation, may alter the composition and integrity of these plastic polymers and plasticizers.	1. Implement strict quality control measures for these containers and choose dialyzers made from safer, less degradable materials to reduce the potential leaching of particulate plastics. 2. Rigorously monitor the dialysate quality to ensure minimal particulate plastic content. 3. Choose sterilization techniques to avoid the degradation of plastics in the dialysis apparatus, maintaining the integrity and safety of the system.
Water Source and treatment methods	- Possible contamination of dialysis water with particulate plastics depends on the water's source and treatment methods (e.g., surface water treatments exhibit higher MP counts than groundwater). - The quality of drinking water utilized in hemodialysis is at risk of being compromised by insufficient filtration, thereby heightening the contamination risks from MPs and DBPs.	1. Enhanced filtration systems: Implement advanced filtration technologies in surface water treatment to reduce particulate plastic counts, focusing on systems capable of effectively removing particulate plastics. 2. Regular monitoring: Frequent and thorough monitoring of water sources for particulate plastic content to assess and adjust treatment processes promptly.

		3. Improved water treatment methods: Employ multi-barrier approaches in water treatment, including pre-oxidation, sedimentation, coagulation-flocculation, and membrane filtration, to enhance the removal efficiency of MPs and DBPs. 4. Use groundwater when possible: Consider groundwater for dialysis, as it typically contains lower levels of particulate plastics than surface water, provided it meets all other safety and quality requirements. 5. Optimize disinfection processes: Balance the use of disinfectants in water treatment to minimize the formation of DBPs while effectively controlling pathogens and ensure carbon filters are regularly maintained and replaced to prevent breakthroughs of contaminants.
Biofilm control measures	-Biofilms can interact with and break down MPs, potentially generating smaller plastic fragments or NPs. -This process can be facilitated by the physical, chemical, and biological activities within the biofilm matrix, exacerbating the release and accumulation of NPs in the environment.	1. Regular cleaning and disinfection of dialysis equipment and water treatment systems to prevent biofilm development. 2. Monitor water pH between 5 and 8.5 and closely monitor water quality.
Staff training and awareness for filtration failures related to RO membranes	-	1. Train staff on new protocols for particulate plastics prevention and the importance of stringent monitoring of water treatment systems. 2. Develop and update protocols as new research emerges, emphasizing preventing particulate plastics from reaching patients. 3. Regular training on particulate plastics contamination prevention should be conducted. 4. Ensure all staff know the potential sources of particulate plastics and preventive measures.

Regular water quality assessments	**-**	1. Implement a monitoring program for regularly assessing particulate plastic levels in treated water and within the dialysis center environment. 2. Establish a response plan for any detected particulate plastic contamination issue to promptly address and mitigate the problem. 3. Stay updated with the latest research on particulate plastics.
Research and development	- Comparing the old with updated strategies, dialysis centers can significantly improve their ability to prevent particulate plastic contamination, ensuring patient safety and the efficacy of dialysis treatments. - Tailoring these strategies to each dialysis center's specific conditions and resources for optimal results is essential.	1. Collaborate with research institutions to stay abreast of the latest findings on particulate plastic contamination and its mitigation. 2. Invest in research initiatives to develop new materials and processes that further reduce particulate plastic contamination risks.

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